ledge of chemistry to comprehend such a list of names and formulæ as is contained in the foregoing quotation. A book constructed on educational lines should not so readily run into details, and should never do so without sufficient explanatory text.

Taking the book generally, it is better than many others of its class, but little more can be said for it. Every geologist will, however, endorse the prefatory remark that "no text-book, however large, can impart an adequate knowledge of geology unless supplemented and controlled by actual contact with the facts of nature."

Annual Report of the Geological Survey of Canada. New series. Vol. vii. 1894. (Ottawa: S. E. Dawson, 1896.)

THIS large volume of over 1200 pages contains, in addition to the Summary Reports of the operations of the Survey for 1894, seven detailed reports on certain portions of the Dominion, and is accompanied by eleven geological maps.

The Summary Report shows that geological work is being carried on by the large staff of the Survey in every part of the Dominion. Especial mention is made of the trial borings now being put down at Athabasca Landing in the North-west Territories, where there is good reason to believe large supplies of oil will be obtained from the Devonian rocks at a depth of about 1500 feet. An account is also given of the recent advances in the development of the mining industry of British Columbia, where of late years such extensive mineral deposits have been discovered, as well as of the explorations in the Labrador peninsula carried out by Mr. Low, who has discovered in this inhospitable region deposits of iron ore which are believed to surpass in size any that have hitherto been discovered in North America.

Of the special reports, two deal with British Columbia: one, by Dr. G. M. Dawson, containing a description of a portion of the interior plateau of that province in the Kamloops district; and the other, by Mr. R. G. McConnell, giving an account of the explorations of the Finlay and Omineca Rivers. These are followed by a report on the country about Red Lake, in Keewatin, by Mr. Dowling. The fourth report is by Dr. R. H. Ells and Dr. F. D. Adams, on a portion of the province of Quebec, comprising the island of Montreal and a part of the eastern townships to the south and east. Mr. Chalmers then describes the superficial geology of the provinces of New Brunswick, Nova Scotia, and Prince Edward Island; while, in the concluding reports, Dr. Hoffmann and Mr. Ingall treat of the chemical work of the Survey and the mineral statistics of the Dominion respectively. Dr. Dawson's report contains an excellent description of the interior plateau of British Columbia from a geological and geographical standpoint. The very extensive development of the Cambrian in this part of the Dominion is noted, as well as the continued volcanic activity from Cambrian to recent times, the volcanic materials, at a very modest computation, having a thickness of 20,000 feet.

Poems of George John Romanes. Pp. xvi + 108. (London: Longmans, Green, and Co., 1896.)

THIS small volume consists of a selection from the poems of the late Mr. George John Romanes. It contains two long poems entitled "A Memorial Poem to Charles Darwin," and "A Tale of the Sea." Both are fine and of a striking quality. Sonnets form the rest of the book, and in many of these the naturalist, as well as the poet, is revealed to us by the accurate descriptions of nature, and the many references to objects and phenomena connected with science. We may add that Mr. T. Herbert Warren, President of Magdalen College, Oxford, has written the introduction, in which he gives a short biographical sketch of the author.

LETTERS TO THE EDITOR.

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts intended for this or any other part of* NATURE. *No notice is taken of anonymous communications.*]

The Pound as a Force, and the Expression of Concrete Quantities generally.

WHAT is Prof. John Perry tilting at in his educational tirade on page 50 of your issue for November 19? To judge from a friendly post-card asking me to reply, he seems to imagine that he is attacking physicists; but apart from this private information I should have imagined that he had in his mind a nearly extinct type of Cambridge text-book, and some—I do not know how many—belated schoolmasters.

Let me assure him, speaking no doubt for others but of most knowledge for myself, that if any student of mine could only express force in poundals and energy in foot-poundals I should be as disgusted as he himself.

One of the first things a student of physics has to learn is that no numerical exercise is fully worked out until it is expressed in units to which he and others are accustomed, and of which they can "feel" the magnitude. As an intermediate step such an expression as 10^7 F.P.S. or C.G.S. units is legitimate enough, but the final answer should be expressed in hours, or days, or other appropriate unit, if time is the subject; in miles, or millimetres, or inches, if it be a length; in hundredweights, or tons, or grammes, or pounds weight, if it be a force; and in ergs, or foot-pounds, or kilogramme-metres, or Joules, or even in kilowatt-hours, if energy be the quantity under consideration.

An educated student speaking to a workman should use the colloquial unit of the shire in which the works are situated; in addressing a foreign correspondent (if orders ever reach this country now from Germany, for instance), he should employ a less insular and more international system; he should, in fact, have no difficulty in making a specification in any conventional system of units to which he has the key.

Prof. Perry asks us to limit ourselves to the C.G.S. system on the one hand, and to the British gravitational system on the other; with those he thinks we can jog along, but with any others we are liable to make mistakes. Does he call that education? If this is the type of "finished engineering student" he is accustomed to, no wonder they "cannot get into works without paying high premiums." (Parenthetically I wonder what premium the Hopkinsons paid in order to be taken into works.) Surely he would not say to a youth training as a banker, "despise all *thalers* and *marks* as trumpery, let us have nothing but good English pounds, and then we shall know where we are, and make no mistakes."

Ah, but, he will say, these units are appropriate to different countries, and you must be able to adapt yourself to the coinage in travelling. Even so! Yet he would seek to limit the physicist, whose range of travel is as wide as the universe. Has he forgotten the variety of subjects with which physical science is concerned? Sometimes there is astronomical energy to be expressed, sometimes thermal, sometimes chemical energy, and sometimes electrical. Would he be content that his educated engineer should be able to express these in nothing but a unit appropriate to the pumping of water out of a mine? When an engineer sees the expression $\frac{1}{2}mv^2$ (which, by the way, he seldom does see; it is generally $wv^2/2g$ in his books, as if gravity were concerned in every transaction of the universe), he is not to think of it straight as momentum multiplied by velocity, or even as inertia multiplied by the square of a velocity, or as energy in any of its protean forms; he is to think of it as a number of foot-pounds. He cannot receive the data in any units whatever and bring out the answer in any other units whatever, one set for the French motor car driver, and another set for the owner, and another for the electrician; no, but he is to say, I must first have the mass given me in pounds, or I may make a mistake; then I must divide the number of pounds by a mystic number, viz. 32·18, in order to bring them to the particular kind of practical unit of inertia which my revered instructor so highly prized; and then I must be told the number of feet per second contained in the velocity (I should be confused by a specification in telegraph posts per minute or kilometres an hour); after that I can do the arithmetic quite nicely, and I remember that the answer always comes out in foot-pounds, which gives no trouble to any one; thus shall my employer not suspect me of being college-taught, and I shall gain advancement in the profession to which I have reason to believe that I was "heaven-born."

Prof. Perry seems in a parlous state, between "friends" who "worship a German soul-destroying fetish," and foes, "academic enemies," who object to the use of the term centrifugal force! Now, I wonder who they are, and why they object to this term. There was once a type of text-book wherein kinetic problems were treated statically, and the centrifugal force exerted by the revolving body was depicted in the diagram and reasoned about as if exerted *upon* the body; does Prof. Perry count among his enemies those who fought against this misleading practice? Again, there appear to be other foes who will not let him use the pound-weight as a unit of force in peace; but is he not a victim of some delusion? A pound-weight or an ounce-weight or a ton-weight are extremely handy force units for actual application, or for calculations dealing with heavy bodies at rest; and an engineer is largely concerned with the statics of heavy bodies, as Prof. Perry truly says, why then should he not use the appropriate unit? Again, when he is pumping water or lifting weights he finds the foot-pound or the kilogram-metre a handy conventional abbreviation for an energy unit: it must be some churl who objects, not a physicist. Was the foot-pound repugnant to Joule? All that a physicist is anxious about in connection with units is that they shall be used accurately and intelligibly, he knows that they are mere agreed-upon conventions, of which some are more generally convenient than others, and he tries to define them conveniently for the practical man's use, and to retain visibly all essential factors; but he is careful not to identify the number of units, or any other mere measure of the thing, with the thing itself.

This last is a point on which some, I fear, are still not clear. Nobody makes this mistake with regard to matter. It can be filed and twisted and heated, &c., it never runs the risk of being thought of as a number of units. Energy is less tangible, and runs more risk of being so maltreated; while as to force, a few philosophers can now be found who teach that force is a mere measure of the time-rate of change of momentum. I wonder if they would say that to a man on the rack!

As to units, I have no objection on principle to hogsheads or kilderkins, but I should seriously object to a student who held that while a pound was a force, a kilogramme was a mass, and at the same time was willing to believe that a kilogramme equalled 2·2 pounds.

To identify weight and mass is barbarous, to denote their units by the same name is unwise, to lose sight of the dimensions of g, and treat it as merely equivalent to 32·18, is illiterate. The whole matter can be put in a nutshell by saying, w and g are both vectors, parallel vectors, and m is their (scalar) ratio.

There are, in fact, three distinct things, all capable of being denoted by such a word as "ton" in common parlance. There is the mass or quantity of material, which concerns us in dealing with markets; there is the inertia or reaction to force, which is important when we are dealing with acceleration; and there is the etherial stress, due to the neighbourhood of the earth, which drives the two pieces of matter together unless they are propped apart.

The last-mentioned curious and ill-understood deportment of two bodies is interesting in itself, and appeals directly to the engineer whenever he has to increase the distance between the earth and another body; it has, indeed, laid such hold of his imagination that he has begun to think it the most fundamental property of matter, and is willing to identify it with the actual substance of the smaller of the two bodies: he is even willing to identify it with its inertia-reaction, especially after division by some arbitrary number suited to himself, his parish, and his work.

May I tell Prof. Perry what is at the root of the perennial debate between engineers and teachers of mechanics?

It is the subject of *acceleration*. An engineer's bodies are nearly always either at rest or in uniform motion, their accelerative stages he is usually able to ignore. The portion of mechanics which serves his need is, therefore, simple enough, and he rebels against more. But the teacher perceives the treatment of acceleration to be the key to mechanics in its higher sense—viz. as an introduction to physics, and as the foundation science of the material universe. He emphasises the idea of inertia, therefore, and sets problems in the accelerative stages of motion, because he knows that there lurk the difficulties and there the soul of the science. He hopes that an engineering student, in these days of a wider application of physics than was common half a century ago, may be willing to learn something more than the mutilated fragment of science which serves for commercial purposes. Sometimes he hopes, but at present he hopes in vain, that the student's own more immediate superiors will refrain from encouraging him in half-knowledge and casual omissions, and the testing of everything by immediate pecuniary results. He hopes that the Engineer, although very busy in his proper domain, may have a sympathetic faith in a larger training, and not inadvertently snuff out any nascent clearness of ideas by ranging himself alongside our true and only natural foes, the powerful obstacles of ignorance, idleness, and prejudice.

Vast improvements in school teaching are possible, and should be strenuously urged. Prof. Perry is now, I suppose, head of the Government teaching of mechanics in this country, and his educational views are no individual concern; but let him discriminate. There is plenty of scope for his warning voice and vigorous sense of the need for contact with realities at every stage. Let him inveigh against wasting time over the fifth book of Euclid, for instance, (if any body now does) and other extravagantly refined conceptions too subtle for the majority of people who have so much to learn of which their teachers are ignorant, let him urge teachers to express common things easily and not only in a scholastic jargon misunderstanded of the people; but, *maxima debetur pueris reverentia*, let him urge clearness of idea and accuracy of speech on all who deal with the junior student. These should not call different things by the same name; these should not be satisfied with lazy and incomplete specifications with essential factors omitted; these should grasp the real and the essential and distinguish from the arbitrary and the conventional, emphasising the one and treating lightly the other, and not considering either themselves or their pupils heaven-born geniuses because unable to grasp fundamental principles.

Above all I ask Prof. Perry to believe that the physicist means something solid when he asserts that formulæ need not all be of the engineering pocket-book type, the type where the units must be stated before an equation is intelligible or useful. Such formulæ are in truth a mere mixture of arithmetic and convention, very useful in their place but not really applied mathematics at all.

Misapprehension on this point is at the bottom of the needless and hampering introduction of units by engineers into every equation; and at the risk of being tiresome, I must once more illustrate the difference between an arithmetical formula of the engineering pocket-book type, and a real mathematical equation, by some simple example. The following may or may not be a sailor's rule, but it is an approximately true and handy one:—

Your height above the sea-level expressed in feet, if square-rooted and multiplied by $\frac{5}{4}$, gives the distance of the visible horizon in miles.

A handy rule I call it, and no more. Your ship's captain who knows that alone is in the position of your engineering student who, whether taught at college at not, has been taught badly, and has not brains enough in himself to supply the deficiency.

The equation, of which the above rule is a convenient but specialised and mutilated version, is $2\,\mathrm{R}h = d^2$. My readers must pardon the triviality of the illustration, and the fact that it is not accurate to the second order of minutiæ, because none of these things matter to my present purpose. The principle I am urging is illustrated well enough by the two points, (1) that the size of the earth, which was omitted from the rule, makes its appearance in the equation, and it is obviously a vital element in the problem; (2) that the equation requires no specification of units, but is complete in itself, and is independent of every system of units that ever were devised; h is not the number of feet, or of metres, or anything else, it is the actual height; d is not the number of miles or of inches to the horizon, but it is the distance itself; and similarly $2\,\mathrm{R}$ is the diameter of the earth, and not any numerical specification of that diameter. The thing, so far as it is true at all, is true from the bottom upwards and entirely true, number and dimensions and everything, with no factor omitted, or slurred over, or suppressed; that, and not the C.G.S. or any other trivial convention, is what is meant by absolute measure. *Ex uno disce omnes.*

Using this trivial example as a type or fable, I say that the college-taught student who knew $2\,\mathrm{R}\,h = d^2$, or its equivalent Euc. III. 36, but could not apply his knowledge to estimate the distance of an iceberg or a hull, though he spent his days at sea, would be an ass, capable of bringing his college-training into well-merited contempt. Also, that the youth who could apply his pocket-book rule, without knowing or seeking the reason of it, would be a useful ignorant machine, creditable enough in the forecastle, passable amidships, but out of place on the bridge, and not to be desired as the product of any educational institution whatever. OLIVER J. LODGE.

University College, Liverpool.

FEW physicists will allow to pass without protest some of Prof. Perry's observations appearing in NATURE of November 19, however reluctant they may be to raise a fresh dispute on the evergreen subject to which they refer. So far as one can gather, the Professor has long since adopted one of the many ways in which the fundamental relation of dynamics may be regarded, and works himself up into a stage fury because the majority of modern physicists regard the question in a somewhat simpler and more correct way.

Prof. Perry has an admirable fondness for kindergarten methods. Let then a beginner be armed with a simple spring balance, made, say, with elastic cord, a small waggon on wheels, a number of masses, a rule, and a clock. By a few simple experiments on a level floor or table, such as one of Prof. Perry's heaven-born engineers should delight in, he can soon be made to convince himself, independently of the units in which he measures, that the rate of increase of velocity α of a body acted on by a force is roughly proportional to the force and inversely as the quantity of stuff in the body. He will thus readily grant, in a general way, that $\alpha = k\frac{F}{m}$, where k is some constant, and will be in a position to understand the absolute truth of this relation later on. If he is an English student, he will have no objection to measure distances in feet, time in seconds, the stuff that he puts into his waggon in pounds, and perhaps the pulls that he applies to his waggon in pounds weight. He will surely admit the propriety of expressing α in (feet per second) added on per second—in the unit sometimes called, on the suggestion, I think, of Prof. Lodge, the "hurry." k then becomes the number g, and the experimenter will easily convince himself that with these units it is about 32. If he is a *bonâ-fide* beginner, I doubt if he will ever make a set of experiments in physics which will afford him more instruction, rough though his results may be.

But with these units k is not quite constant: not *absolutely* so even if the standard pound is kept in London, Prof. Perry notwithstanding. And, incidentally, is an engineer who loads the lever of his safety-valve with a bucketful of bricks in other latitudes in just the same position as if he did the same in London? Not that I intend to imply that variations in g matter much to the professional work of men who (very properly) compound for any little discrepancy between their calculations and the ways of nature by liberal use of factors of safety, of trifling magnitudes such as 10.

We pass then to the conception of absolute measurement, the interest and value of which are not reserved exclusively for those who use the C.G.S. system, but exist in all systems. We can make $k = 1$, and write the fundamental equation in the form $\alpha = \frac{F}{m}$, most readily by adopting either of two conventions, (1) by expressing matter in pounds and forces in terms of a unit the gth part of a pound weight (the poundal); or (2) by expressing forces in the approximately constant unit the pound-weight, and matter in a new unit, also approximately constant, consisting of g pounds. Of these two alternatives Prof. Perry chooses the last. It is also the worst, for four reasons at least, viz.:

(1) That the system is needlessly complicated, through demanding the conception of two standard portions of matter; namely, the standard pound-mass whose weight is the unit of force, and the "engineer's unit" of mass or inertia (*teste* Perry) of 32·18 pounds.

(2) That the unit of force is variable or vague, unless careful reservations are made.

(3) That the unit of mass is ditto, ditto.

(4) That a majority of those who use any such system at all, already use, largely for the above reasons, the other convention, involving the idea of the poundal.

And no amount of abuse or sophistry from the non-orthodox will get over the fact that so long as we have as standards a foot, a second, and a lump of matter that we call a pound, and so long as we think of forces as we do at present, that force which, acting on that lump of matter, would give it an acceleration of one (foot per second) per second must always have a singular interest for us, entitling it to rank as a unit even with those who personally may be content to reckon the forces with which they have to deal in some other way.

But why should Prof. Perry be so dissatisfied? His students make no mistakes, and by the adoption of his shibboleth the very tender blossoms for whom he pleads will be enabled to produce luxuriant crops in the profession for which they seem so unfit. Can it be that in attempting, for instance, to become electrical as well as mechanical engineers, they find a horrible gulf between the artificial system they know and the C.G.S. units they will have to use?

And what right has the Professor to assume that all real engineers regard the question as he does? I wonder what percentage actually do so. On what platform, for instance, is Prof. Greenhill just now, to whom the idea of mass is as if it were not, absolute measurement an accursed thing, and, above all, that relic of the dark ages, Prof. Perry's 32·18 lb. unit, Anathema? If only these champions of rival heresies can be persuaded to demolish one another, there will be for the orthodox a great peace. M. J. JACKSON.

Oxford, November 24.

MAY I, as a teacher of physics, many of whose pupils enter the engineering profession, be allowed to say a word in my own defence in reply to Prof. J. Perry's scorn, expressed in an article, "The Force of One Pound," in NATURE of November 19, vol. lv. p. 49, for those who, like myself, teach my pupils the use of the poundal in dynamical calculation.

I am sure that Prof. Perry agrees with me in looking at an absolute system of measurement, whether British or metrical, as the only logical one, and where for practical purposes change of unit has to be made, there seem to me to be two courses open: (1) to make such a change in one, or all, of the fundamental units and work *ab initio* with these changed units; or (2) to work in absolute units, converting the absolute into the practical unit, by means of multiplication by a suitable factor, or, in other words, to introduce a constant of variation, different from unity, into our equations. I prefer to adopt the latter alternative where units of force have to be expressed in practical pound-weight.

Prof. Perry seems to suggest a third course, and asks us to begin with an absolute system in which the unit of force is to be one of our absolute units, the other two presumably being the ordinary foot and second. Of course, a system of theoretical dynamics could be built upon this basis, but to teach it, as we are invited to do, side by side with the C.G.S. system, would confuse the mind of any pupil unless he were an engineering student.

But there is another branch of engineering science in which exactly the same thing has to be done, namely, electrical science. Here, too, we have a system of equations which are invariably expressed in absolute C.G.S. measure, that is, in terms of units not practically in use. Here we may again either work out anew the formulæ, choosing as unit of length the quadrantal arc of the earth (10^9 cm.), and as unit of mass the 10^{-11} gm., or, as I prefer, employ the ordinary formulæ and multiply the result obtained from it by the appropriate factor when wishing to reduce the result to practical volts or amperes; or is there still a third method in which volts and amperes become the fundamental units in terms of which lengths and forces have to be measured? L. CUMMING.

Rugby, November 23.

Recent Work on the Madreporarian Skeleton.

I SHOULD like to draw attention here to a paper just published on the skeleton of Madreporaria, by Dr. von Koch, Professor of Zoology in Darmstadt, in the Gegenbaur *Festschrift*. Some time ago, in November 1895, an "abstract" was published by me in the *Proceedings* of the Royal Society, vol. lix., embodying the results of a full paper entitled, "Microscopic and Systematic Study of Madreporarian Corals." The full paper, with very numerous illustrations, will be published this month in the *Philosophical Transactions*. Prof. v. Koch does not mention this abstract in his reference-list of literature. It will be all the more interesting to those who may happen to be familiar with both papers to have set before them the more important points